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(54) Title: T CELL RECEPTOR Vβ-Dβ-Jβ SEQUENCE AND METHODS FOR ITS DETECTION

(57) Abstract

In one embodiment, the present invention is directed to a first oligonucleotide comprising the sequence of or derived from 5'-CTAGGGCGGGCGGGACTCACCTAC-3' or the nucleic acid sequence complementary thereto. The first oligonucleotide can be used with a nucleic acid of between 15 and 30 nucleotides that does not comprise the sequence of the first oligonucleotide and is found in the region from Vβ to Jβ of the Vβ13.1 gene in Vβ13.1 T cells, wherein the sequences of the oligonucleotide and the nucleic acid are not found on the same strand of the Vβ13.1 gene pair, to amplify a portion of the Vβ13.1 gene. Alternatively, the first oligonucleotide can be used with a labeling moiety in methods of detecting a LGRAGLTY motif found in T cell receptors of Vβ13.1 T cells. This motif is associated with autoimmune diseases, such as multiple sclerosis (MS). Once the motif is detected, the autoimmune disease can be treated or its progress monitored. The autoimmune disease can be treated by administering a peptide comprising the LGRAGLTY motif.

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T CELL RECEPTOR Vβ-Dβ-Jβ SEQUENCE AND METHODS FOR ITS DETECTION

BACKGROUND OF THE INVENTION

The United States government may own rights in the present invention pursuant to grant number NS36140 from the National Institutes of Health.

1. Field of the Invention

The present invention relates generally to the field of treatment of autoimmune disease, such as multiple sclerosis (MS). More particularly, it concerns a T-cell receptor sequence found in some MS patients, and methods for its detection.

2. Description of Related Art

In humans and other mammals, T cell receptors are found on T cells. T cell receptors comprise α and β chains, with β chains comprising the following regions from N-terminus to C-terminus: Vβ-Dβ-Jβ-Cβ. T cell receptors naturally vary in the Vβ-Dβ-Jβ regions.

When an antigen is presented to the T cells by an antigen-presenting cell (APC), a T cell receptor with variable regions (including Vβ-Dβ-Jβ) that so happen to recognize the antigen binds to the antigen on the APC. The T cell bearing the T cell receptor then undergoes activation (clonal expansion).

The pathogenesis of a number of autoimmune diseases is believed to lie in autoimmune T cell responses to antigens presented normally by the organism. An example of such a disease is multiple sclerosis (MS), which is generally held to arise in T cell responses to myelin antigens, in particular myelin basic protein (MBP). MBP-reactive T cells are found to undergo *in vivo* activation, and occur at a higher precursor frequency in blood and cerebrospinal fluid in patients with MS as opposed to control individuals. These MBP-reactive T cells produce Th1 cytokines, *e.g.* IL-2, TNF, and γ-interferon. These Th1 cytokines facilitate migration of inflammatory cells into the

central nervous system and exacerbate myelin-destructive inflammatory responses in MS.

A number of regulatory mechanisms can be made use of in the treatment of MS. One such is vaccination with one or more of the limited number of T cell membrane-associated peptides with extracellular domains. Vandenbark, U.S. Patent 5,614,192, discloses treatment of autoimmune diseases by the use of immunogenic T cell receptor peptides of 15 to 30 amino acids comprising at least part of the second complementarity determining region (CDR2) of the T cell receptor. A copending U.S. Patent Application by Zhang (60/099,102) discloses treatment of autoimmune diseases by use of immunogenic T cell receptor peptides in combination with immunogenic T cell activation marker peptides.

One area in which vaccination with T cell receptor peptides can be improved is by determining which, if any, common motifs are found in the T cell receptors of a patient with an autoimmune disease such as MS. If such motifs are found, then the patient can be vaccinated with peptides identical to the motifs, in order to facilitate treatment.

Therefore, it is desirable to have the amino acid sequences of common motifs found in the T cell receptors of patients with autoimmune diseases. It is also desirable to be able to readily detect such motifs in a patient sample by a convenient method, such as PCR. In addition, it is desirable to use peptides identical to the detected motifs to treat a patient with the autoimmune disease.

The present invention discloses such a common motif found in the T cell receptors of a subset of Vβ13.1 T cells, the "LGRAGLTY motif", which has the amino acid sequence Lue Gly Arg Ala Gly Leu Thr Tyr (SEQ ID NO: 3), as well as a method for its ready detection by PCR. This motif is found in some T cell receptors of some T cells that recognize amino acids 83-99 of MBP (hereinafter "MBP83-99"). The motif in the context of this subset of Vβ13.1 T cells may hereinafter be referred to as "Vβ13.1-LGRAGLTY." Peptides identical to the motif can be used to vaccinate patients in order to treat or prevent autoimmune diseases with which Vβ13.1-LGRAGLTY is associated. One such autoimmune disease is MS.

SUMMARY OF THE INVENTION

In one embodiment, the present invention is directed to an oligonucleotide from about 15 to 30 nucleotides in length which comprises at least 10 contiguous nucleotides of SEQ ID NO:1, or a sequence complementary thereto or derived therefrom. Even more preferable is an oligonucleotide, of about 15 to 30 nucleotides in length, which comprises 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, or 23 contiguous nucleotides of SEQ ID NO:, or a sequence complementary thereto. Most preferable is an oligonucleotide, of about 15 to 30 nucleotides in length, which comprises the nucleotide sequence of SEQ ID NO:1, or the sequence complementary thereto.

In a series of further embodiments, the oligonucleotide can be used in amplification or detection of a nucleic acid sequence found in Vβ13.1-LGRAGLTY T cells. In one subseries of such embodiments, the oligonucleotide is used in a primer pair, the primer pair comprising or derived from:

(a) a first primer which is an oligonucleotide is from about 15 to 30 nucleotides in length and comprises at least 10 contiguous nucleotides of SEQ ID NO:1, or a sequence complementary thereto; and

(b) a second primer which is an oligonucleotide of about 15 and 30 nucleotides in length that does not comprise the sequence (a), and said second primer sequence can be found in the region from Vβ to Jβ of the Vβ13.1 gene (SEQ ID NO: 2) in T cell receptor T cells,

wherein the sequences of (a) and (b) are not found on the same strand of the T cell receptor gene.

Preferably said first primer is an oligonucleotide, of about 15 to 30 nucleotides in length, which comprises 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, or 23 contiguous nucleotides of SEQ ID NO:1, or a sequence complementary thereto. Most preferable is an oligonucleotide, of about 15 to 30 nucleotides in length, which comprises the nucleotide sequence of SEQ ID NO:1, or the sequence complementary thereto.

In another subseries of such embodiments, the oligonucleotide is used as an oligonucleotide probe, the oligonucleotide probe comprising:

(a) an oligonucleotide from about 15 to 30 nucleotides in length and comprises at least 10 contiguous nucleotides of SEQ ID NO:1, or a sequence complementary thereto; and

(b) a labeling moiety.

Preferably, the oligonucleotide, is about 15 to 30 nucleotides in length, and comprises 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, or 23 contiguous nucleotides of SEQ ID NO:1, or a sequence complementary thereto. Most preferable is an oligonucleotide, of about 15 to 30 nucleotides in length, which comprises the nucleotide sequence of SEQ ID NO:1, or the sequence complementary thereto. The labeling moiety is preferably selected from ^{32}P or digoxingenin.

In another embodiment, the present invention is directed to a method of detecting MBP83-99 Vβ13.1 T cells expressing a LGRAGLTY motif, comprising:

(i) obtaining a nucleic acid sample from MBP83-99 Vβ13.1 T cells;

(ii) contacting the nucleic acid sample with a primer pair selected or derived from:

(a) a first primer comprising an oligonucleotide of about 15 to 30 nucleotides in length and comprises at least 10 contiguous nucleotides of SEQ ID NO:1, or a sequence complementary thereto or derived therefrom; and

(b) a second primer comprising and oligonucleotide of about 15 and 30 nucleotides in length that does not comprise the sequence of (a) and is found in the region from Vβ to Jβ of the Vβ13.1 gene in Vβ13.1 T cells (SEQ ID NO:2),

wherein the sequences of (a) and (b) are not found on the same strand of the Vβ13.1 gene; and,

(iii) detecting the presence of the nucleic acid encoding the LGRAGLTY motif.

Preferably the first primer is an oligonucleotide, of about 15 to 30 nucleotides in length, which comprises 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, or 23 contiguous nucleotides of SEQ ID NO:, or a sequence complementary thereto. Most preferable is an oligonucleotide, of about 15 to 30 nucleotides in length, which comprises the nucleotide sequence of SEQ ID NO:1, or the sequence complementary thereto.

In yet another embodiment, the present invention is directed to a method of treating an autoimmune disease, comprising:

(a) obtaining MBP83-99 Vβ13.1 T cells from a human;

(b) detecting the presence of a nucleic acid encoding the LGRAGLTY motif by the method described above; and, if the nucleic acid is detected,

(c) administering an Lue Gly Arg Ala Gly Leu Thr Tyr (SEQ ID NO: 3) peptide to the human.

In a still further embodiment, the present invention is directed to a method of monitoring an autoimmune disease, comprising:

(a) obtaining MBP83-99 Vβ13.1 T cells from a human;

(b) detecting the presence of a nucleic acid encoding the LGRAGLTY motif by the method described above; and, if the nucleic acid is detected,

(c) quantifying the nucleic acid.

BRIEF DESCRIPTION OF THE DRAWINGS

The following drawings form part of the present specification and are included to further demonstrate certain aspects of the present invention. The invention may be better understood by reference to one or more of these drawings in combination with the detailed description of specific embodiments presented herein.

Figure 1 shows the experimental procedure for cloning and sequencing of PBMC-derived PCR products. cDNA derived from PBMC specimens were amplified by the 5'Vβ13.1 primer and the 3'Jβ primer from four PBMC specimens positive for the expression of the LGRAGLTY motif were ligated into the TA cloning vector pCR2.1 and transformed into *E. coli*. Plasmid DNA was screened by PCR with a M13 primer and the LGRAGLTY-specific primer. The positive plasmids that showed visible amplification by PCR were sequenced for VβDβJβ sequences with a Vβ13.1 primer.

Figure 2 shows reactivity patterns of two MBP83-99 T cell clones to analog peptides with single alanine substitutions. Two pairs of MBP83-99 T cell clones that exhibited identical Vβ13.1 rearrangements (for MS7-E2.6 and MS27-C3.1) and a similar Vα-Jα junctional sequence (for MS7-E2.6 and MS7-E3.1) were examined for reactivity

to a panel of alanine substituted peptides in [^{3}H]-thymidine incorporation assays. A mouse fibroblast cell line expressing DRB1*1501 was used as a source of antigen-presenting cells. The proliferative responses of the clones to each analog peptide were measured after 72 hours and the results are presented as CPM incorporated. The shaded boxes represent > 50% decrease in the proliferation of the T cell clones in response to analog peptides.

Figure 3 shows cross-examination of the specificity of CDR3 oligonucleotides with original and unrelated T cell clones. A set of oligonucleotides specific for TCR VDJ region of were examined for their specificity in detecting known target DNA sequences present in original MBP83-99 T cell clones as well as in unrelated MBP83-99 T cell clones derived from the same and different individuals. PCR reactions using CDR3-specific oligonucleotides as the forward primers and a 3'-Cβ primer as the reverse primer performed. Solid boxes represent positive detection of DNA sequences present in original T cell clones or T cell clone(s) sharing the same CDR3 sequences. All primers were also examined for their binding to DNA products of randomly selected T cell clones that had unrelated CDR3 sequences (shaded boxes).

Figure 4 shows detection of target DNA sequence complementary to motif Vβ13.1-LGRAGLTY in randomly selected PBMC specimens derived from patients with MS. cDNA prepared from PBMC specimens from randomly selected MS patients (n = 48) were first amplified in RT-PCR using a 5'-Vβ13.1 specific primer and a 3'-Cβ primer. The amplified PCR products were then hybridized subsequently with a digoxigenin-labeled oligonucleotide probe specific for the LGRAGLTY motif. The original MBP83-99 clone (MS7-E2.6) and an unrelated T cell clone (MS32-B9.8) were used as positive and negative controls, respectively. MS-7 and MS-27 were the original PBMC specimens from which clone MS7-E2.6 (MS-7 in Table 1) and clone MS27-C3.1 (MS-27 in Table 1) were derived. Asterisks indicate positive expression of DRB1*1501.

Figure 5 shows detection of the Vβ13.1-LGRAGLTY motif in randomly selected PBMC specimens derived from normal subjects. PBMC specimens obtained from 20 normal subjects (NS) were analyzed under the same condition as described in the Figure 4 legend. The original clone (MS7-E2.6) and an unrelated T cell clone (MS32-B9.8)

were used as positive and negative controls, respectively. Asterisks indicate positive expression of DRB1*1501.

Figure 6 shows semi-quantitative comparason of the expression of the LGRAGLTY motif in PBMC specimens derived from MS patients and normal subjects. The expression of motif Vβ13.1-LGRAGLTY was analyzed by semi-quantitative PCR relative to the Cβ expression in each cDNA derived from PBMC of MS and normal individuals. The relative expression level was calculated as (expression of the LGRAGLTY motif/Expression of Cβ) x 100%.

Figure 7 shows detection of the Vβ13.1-LGRAGLTY motif in short-term MBP83-99 T cell lines derived from patients with MS. A panel of independent short-term MBP83-99 T cell lines were generated from five patients with MS using a synthetic 83-99 peptide of MBP. All these T cell lines were confirmed for their specific reactivity to MBP83-99 peptide (CPM in response to MBP83-99 / control CPM > 5). cDNA products were amplified using a 5'-Vβ13.1 specific primer and a 3'-Cβ primer in PCR. The amplified PCR products were hybridized subsequently with a digoxigenin-labeled oligonucleotide probe corresponding to the Vβ13.1-LGRAGLTY motif in a Southern blot analysis. cDNA products derived from the original MBP83-99 clone (MS7-E2.6) and a unrelated T cell clone (MS32-B9.8) were used as positive and negative controls, respectively.

DESCRIPTION OF PREFERRED EMBODIMENTS

To aid in understanding the invention, several terms are defined below.

"PCR" means the polymerase chain reaction, for example, as generally described in U.S. Patent No. 4,683,202 (issued July 28, 1987 to Mullins), which is incorporated herein by reference. PCR is an amplification technique wherein selected oligonucleotides, or primers, are hybridized to nucleic acid templates in the presence of a polymerization agent (such as polymerase) and four nucleotide triphosphates, and extension products are formed from the primers. These products are then denatured and used as templates in a cycling reaction that amplifies the number and amount of existing

nucleic acids to facilitate their subsequent detection. A variety of PCR techniques are available and may be used with the methods according to the invention.

"Primer" means an oligonucleotide, whether natural or synthetic, capable of acting as a point of initiation of DNA synthesis complementary to a specific DNA sequence on a template molecule.

"Derived from," in the context of the term "primer(s) or probe(s) derived from," means that the primer or probe is not limited to the nucleotide sequence(s) listed, but also includes variations in the listed nucleotide sequence(s) including nucleotide additions, deletions, or substitutions to the extent that the variations to the listed sequence(s) retain the ability to act as a primer in the detection of T cell receptor DNA encoding the Vβ13.1-LGRAGLTY sequence, *i.e.* Lue Gly Arg Ala Gly Leu Thr Tyr (SEQ ID NO: 3).

"Immunogenic," when used to describe a peptide, means the peptide is able to induce an immune response, either T cell mediated, antibody, or both. "Antigenic" means the peptide can be recognized in a free form by antibodies and in the context of MHC molecules in the case of antigen-specific T cells.

"Immune-related disease" means a disease in which the immune system is involved in the pathogenesis of the disease. A subset of immune-related diseases are autoimmune diseases. Autoimmune diseases contemplated by the present invention include, but are not limited to, rheumatoid arthritis, myasthenia gravis, multiple sclerosis, systemic lupus erythematosus, autoimmune thyroiditis (Hashimoto's thyroiditis), Graves' disease, inflammatory bowel disease, autoimmune uveoretinitis, polymyositis, and certain types of diabetes. In view of the present disclosure, one skilled in the art can readily perceive other autoimmune diseases treatable by the compositions and methods of the present invention. "T cell mediated disease" means a disease brought about in an organism as a result of T cells recognizing peptides normally found in the organism.

"Treatment" or "treating," when referring to protection of an animal from a disease, means preventing, suppressing, or repressing the disease. Preventing the disease involves administering a composition of the present invention to an animal prior to induction of the disease. Suppressing the disease involves administering a composition of the present invention to an animal after induction of the disease but before its clinical

appearance. Repressing the disease involves administering a composition of the present invention to an animal after clinical appearance of the disease. It will be appreciated that in human medicine it cannot always be known when in the course of disease induction a composition of the present invention will be administered.

In one aspect, the present invention is directed to a primer pair comprising the sequence of or derived from:

(a) a first primer which is an oligonucleotide of about 15 to 30 nucleotides in length, comprising at least 10 contiguous nucleotides of SEQ ID NO: 1, or the nucleic acid sequence complementary thereto; and

(b) a second primer which is an oligonucleotide of about 15 and 30 nucleotides in length that does not comprise a sequence of (a) and is found in the region from Vβ to Jβ of the T cell receptor gene in Vβ13.1 T cells,

wherein the sequences of (a) and (b) are not found on the same strand of the T cell receptor gene.

Preferably, said first primer is an oligonucleotide, of about 15 to 30 nucleotides in length, which comprises 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, or 23 contiguous nucleotides of SEQ ID NO:, or a sequence complementary thereto. Most preferable is an oligonucleotide, of about 15 to 30 nucleotides in length, which comprises the nucleotide sequence of SEQ ID NO:1, or the sequence complementary thereto.

The primers according to the invention are designed to amplify a fragment of a gene encoding T cell receptor of human Vβ13.1 T cells, the fragment comprising an amino acid motif Lue Gly Arg Ala Gly Leu Thr Tyr (SEQ ID NO: 3). The gene from Vβ13.1 T cells encoding the T cell receptor comprising the LGRAGLTY motif has been submitted to GenBank, accession number AF117132. The sequence of the gene from Vβ13.1 T cells encoding the T cell receptor comprising the LGRAGLTY motif is given herein as SEQ ID NO: 2. In the method according to the invention, a fragment of about 400 bp of the T cell receptor gene from Vβ13.1 T cells is amplified using two primers, wherein the first primer is in the CDR3 region, and the second primer is in the Cβ region. The Vβ-Dβ-Jβ region of the T cell receptor gene will be between the CDR3 and Cβ

regions, inclusive. In a preferred embodiment, the primers are the primer pair described above.

Primers according to the invention also include oligonucleotides that are derived from the primers (a) - (b). A sequence is derived from a primer (a) or (b) if it has or contains substantially the same sequence as one of the primers and retains the ability to selectively anneal to approximately the same CDR3 or Cβ region of the Vβ-Dβ-Jβ region of the T cell receptor gene from Vβ13.1 T cells as described above. More particularly, the primer may differ from a primer (a) or (b) in length or by the kind of nucleic acid in one or more positions along the sequence, as long as it retains selectivity for the identified regions of the Vβ-Dβ-Jβ region of the T cell receptor gene from Vβ13.1 T cells. For example, the primer may be an oligonucleotide having at least 15 nucleotides, wherein the 15 nucleotides are identical with a series of 15 contiguous nucleic acids selected or derived from a sequence of the primers (a) - (b). The primer may also be any oligonucleotide of about 30 nucleotides or less comprising a segment having the sequence selected or derived from any of primers (a) - (b). The number of nucleotides in the primer should be high enough to retain selectivity, yet low enough to retain efficiency and operability in primer synthesis and the PCR procedure. The primer may have variations including nucleotide deletions, additions, or substitutions to the extent that the variations to the sequence of primers (a) - (b) retain the ability to act as a primer in the detection of Vβ13.1-LGRAGLTY.

The Vβ13.1-LGRAGLTY detection method according to the invention uses a pair of the above primers in a procedure that detects the presence of any Vβ13.1-LGRAGLTY in a sample. The sample to be tested for the presence of Vβ13.1-LGRAGLTY is a nucleic acid, preferably DNA. The DNA can be genomic DNA, cDNA, DNA previously amplified by PCR, or any other form of DNA. The sample can be isolated, directly or indirectly, from any animal or human bodily tissue that expresses T cell receptor β chain genes. A preferred bodily tissue is peripheral blood mononuclear cells (PBMC). If the sample is genomic DNA, it can be isolated directly from the bodily tissue. If the sample is cDNA, it is isolated indirectly by reverse transcription of mRNA directly isolated from the bodily tissue. If the sample is DNA previously amplified by

PCR, it is isolated indirectly by amplification of genomic DNA, cDNA, or any other form of DNA.

In a preferred embodiment, a portion of the T cell receptor gene from Vβ13.1 T cells, the portion comprising a sequence encoding the LGRAGLTY motif, is amplified to enhance the ability to detect the presence of Vβ13.1-LGRAGLTY (5'-CTAGGGCGGGCGGGACTCACCTAC-3' (SEQ ID NO: 1)). The amplification can take place via a PCR reaction, using any particular PCR technique or equipment that provides sensitive, selective and rapid amplification of the portion in the sample.

For example, the PCR amplification can follow a procedure wherein a reaction mixture is prepared that contains the following ingredients: 5 μL 10 x PCR buffer II (100 mM Tris-HCl, pH 8.3, 500 mM KCl), 3 μL 25 mM $MgCl_2$, 1 μL 10 mM dNTP mix, 0.3 μL *Taq* polymerase (5 U/μL) (AmpliTaq Gold, Perkin Elmer, Norwalk, CT), 30 pmol of primer A, and 30 pmol of primer B. In light of the present disclosure, the skilled artisan will be able to select appropriate primers A and B for the purpose of PCR amplification of the portion of the T cell receptor gene from Vβ13.1 T cells. The above mixture is appropriate for amplifying 1 μL of sample DNA. Hereinafter, the DNA to be amplified may be referred to as the "template."

Once sample DNA is added to the above reaction mixture, the PCR reaction can be performed with an amplification profile of 1 min at 95°C (denaturation); 20 sec at 56°C (annealing), and 40 sec at 72°C (extension) for a total of 35 cycles.

In the PCR reaction, the template can be heat denatured and annealed to two oligonucleotide primers. The oligonucleotides bracket an area of the nucleic acid sequence that is to be amplified. A heat stable DNA polymerase is included in the reaction mixture. The polymerase elongates the primers annealed to complementary DNA by adding the appropriate complementary nucleotides. Preferred polymerases have the characteristics of being stable at temperatures of at least 95°C, have a processivity of 50-60 and have an extension rate of greater than 50 nucleotides per minute.

Approximately 40 PCR cycles are used in a typical PCR amplification reaction. However, certain PCR reactions may work with as few as 15 to 20 cycles or as many as

50 cycles. Each cycle consists of a melting step in which the template is heated to a temperature above about 95°C.

The temperature of the PCR reaction is then cooled to allow annealing of the primers to the template. In this annealing step, the reaction temperature is adjusted to between about 55°C to 72°C for approximately 20 seconds. Longer or shorter times may work depending upon the specific reaction.

The temperature of the PCR reaction is then heated to allow maximal elongation of the primers to be effected by the polymerase. In this extension step, the reaction temperature is adjusted to between about 70°C and 75°C for approximately 40 seconds. Higher or lower temperatures and/or longer or shorter times may work depending upon the specific reaction.

In addition, before the first cycle is begun, the reaction mixture can undergo an initial denaturation for a period of about 5 min to 15 min. Similarly, after the final cycle is ended, the reaction mixture can undergo a final extension for a period of about 5 min to 10 min.

Amplification can be performed using a two-step PCR. In this technique, a first PCR amplification reaction is performed to amplify a first region that is larger than, and comprises, a region of interest. A second PCR amplification reaction is then performed, using the first region as a template, to amplify the region of interest. If either primer from the first PCR reaction can be used in the second PCR reaction, the second PCR reaction is "semi-nested." If neither primer from the first PCR reaction can be used in the second PCR reaction, the second PCR reaction is "nested."

In a preferred way of performing the method of the present invention, the Vβ13.1-LGRAGLTY motif is amplified by two-step PCR. In the first PCR reaction, the sample is amplified using a first primer that anneals to the Vβ region of the T cell receptor gene and a second primer that anneals to the Cβ region of the T cell receptor gene, using the reaction mixture and profile disclosed above. The first PCR reaction amplifies a first region that is about 600 bp and extends from Vβ through the Vβ-Dβ-Jβ junction to Cβ. The second PCR reaction is nested or semi-nested; a portion of the first

region is partially amplified using primer pair (a) - (b). The second PCR reaction amplifies the region of interest.

After amplification of any DNA encoding Vβ13.1-LGRAGLTY in the sample, the amplification product is detected. This detection may be done by a number of procedures. For example, an aliquot of amplification product can be loaded onto an electrophoresis gel, to which an electric field is applied to separate DNA molecules by size. In another method, an aliquot of amplification product is loaded onto a gel stained with SYBR green, ethidium bromide, or another molecule that will bind to DNA and emit a detectable signal. For example, ethidium bromide binds to DNA and emits visible light when illuminated by ultraviolet light. A dried gel could alternatively contain a radio- or chemically-labeled oligonucleotide (which may hereinafter be termed an "oligonucleotide probe") complementary to a portion of the sequence of the amplified template, from which an autoradiograph is taken by exposing the gel to film.

In another embodiment, the present invention relates to an oligonucleotide probe, comprising

(a)a oligonucleotide of about 15 to 30 nucleotides in length, comprising at least 10 contiguous nucleotides of SEQ ID NO:1, or the nucleic acid sequence complementary thereto; and

(b) a labeling moiety.

Preferably "(a)" is an oligonucleotide, of about 15 to 30 nucleotides in length, which comprises 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, or 23 contiguous nucleotides of SEQ ID NO:1, or a sequence complementary thereto. Most preferable is an oligonucleotide, of about 15 to 30 nucleotides in length, which comprises the nucleotide sequence of SEQ ID NO:1, or the sequence complementary thereto. Preferably, the labeling moiety is selected from ^{32}P or digoxingenin.

A typical radiolabeled oligonucleotide useful for detection of amplification products produced using primers of the present invention is taken from the Vβ-Dβ-Jβ region. If the Vβ13.1-LGRAGLTY region is amplified by the two-step semi-nested PCR disclosed above, wherein a primer corresponding to the sequence encoding the LGRAGLTY motif is used, any oligonucleotide of about 10 or more nucleotides, and

preferably about 18 or more nucleotides, that is complementary to a portion of either strand of the amplified Vβ13.1-LGRAGLTY region can be used. More preferably, the oligonucleotide 5'-CTAGGGCGGGCGGGACTCACCTAC-3' (SEQ ID NO: 1) or the nucleic acid sequence complementary thereto is used as a probe.

The present invention also comprises a test kit, comprising at a first primer (a) of about 15 to 30 nucleotides in length comprising at least 10 contiguous nucleotides of SEQ ID NO: 1, or an the nucleic acid sequence complementary thereto.

In one preferred embodiment, the test kit further comprises a second primer (b), wherein the second primer is a nucleic acid sequence of about 15 and 30 nucleotides in length that does not comprise the sequence of (a) and is found in the region from Vβ to Jβ of the Vβ13.1 T cell receptor gene in T cells,

wherein the sequences of (a) and (b) are not found on the same strand of the T cell receptor gene.

More preferably said first primer is an oligonucleotide, of about 15 to 30 nucleotides in length, which comprises 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, or 23 contiguous nucleotides of SEQ ID NO:1, or a sequence complementary thereto. Most preferable is an oligonucleotide, of about 15 to 30 nucleotides in length, which comprises the nucleotide sequence of SEQ ID NO:1, or the sequence complementary thereto

In this embodiment, the test kit further comprises at least one reagent useful in the amplification of Vβ13.1-LGRAGLTY DNA by PCR techniques as described above. Exemplary reagents that can be included in the kit include, but are not limited to, buffers, deoxynucleoside triphosphates, heat-stable DNA polymerase such as *Taq* polymerase, Vβ13.1-LGRAGLTY DNA for positive control, and non-Vβ13.1-LGRAGLTY DNA for negative control. Other reagents that can be included in the test kit are known to one skilled in the art.

In another preferred embodiment, the test kit further comprises a labeling moiety. Preferably the labeling moiety is ^{32}P or digoxingenin.

The present invention also comprises a method of treating an autoimmune disease. The disease is one in which, for at least some patients, T cell receptors comprising LGRAGLTY are found on Vβ13.1 T cells. Other types of T cells, and/or

Vβ13.1 T cells which lack T cell receptors comprising the LGRAGLTY motif, may be presented by the patient.

The method of treating the autoimmune disease comprises:

(a) obtaining MBP83-99 Vβ13.1 T cells from a human;

(b) detecting in the T cells the presence of a nucleic acid encoding a LGRAGLTY motif by the methods disclosed above; and, if the nucleic acid is detected,

(c) administering an Lue Gly Arg Ala Gly Leu Thr Tyr (SEQ ID NO: 3) peptide to the human.

The autoimmune disease can be any autoimmune disease in which T cell receptors comprising the LGRAGLTY motif are found on Vβ13.1 T cells. Autoimmune diseases contemplated by the present invention include, but are not limited to, rheumatoid arthritis, myasthenia gravis, multiple sclerosis, systemic lupus erythematosus, autoimmune thyroiditis (Hashimoto's thyroiditis), Graves' disease, inflammatory bowel disease, autoimmune uveoretinitis, polymyositis, and certain types of diabetes. A preferred autoimmune disease is multiple sclerosis (MS).

If nucleic acid encoding an LGRAGLTY motif is detected by the methods disclosed above, the autoimmune disease can be treated by administering a peptide comprising Lue Gly Arg Ala Gly Leu Thr Tyr (SEQ ID NO: 3). The peptide can be administered alone, or in combination with a T cell activation marker peptide. Preferably the peptide is administered in combination with a T cell activation marker peptide, according to the disclosure of Zhang, U.S. Patent Application 60/099,102, incorporated herein by reference. Administration of the peptide can lead to an immunogenic response, wherein the patient will develop antibodies and T cell receptors that recognize and bind to the LGRAGLTY motif of T cell receptors found on Vβ13.1 T cells.

Because Vβ13.1-LGRAGLTY can be present in both patients suffering from MS and normal individuals who are not suffering from the disease, it is envisioned that an Lue Gly Arg Ala Gly Leu Thr Tyr (SEQ ID NO: 3) peptide can be administered to both patients with MS and normal individuals.

In an alternative embodiment, if nucleic acid encoding an LGRAGLTY motif is detected by the methods disclosed above, the autoimmune disease can be monitored by

quantifying the nucleic acid. The greater the amount of the nucleic acid present in a sample, such as PBMC, the greater the number of Vβ13.1 T cells and the greater the likely severity of symptoms of the autoimmune disease. Also, depending on the time between the presentation of elevated Vβ13.1 T cell levels and the appearance of symptoms, the clinician may receive an opportunity to apply treatments intended to minimize the severity of the symptoms and/or treat the disease before the symptoms appear.

The following examples are included to demonstrate preferred embodiments of the invention. It should be appreciated by those of skill in the art that the techniques disclosed in the examples which follow represent techniques discovered by the inventor to function well in the practice of the invention, and thus can be considered to constitute preferred modes for its practice. However, those of skill in the art should, in light of the present disclosure, appreciate that many changes can be made in the specific embodiments which are disclosed and still obtain a like or similar result without departing from the spirit and scope of the invention.

EXAMPLES

Example 1

T cell receptor Vβ-Dβ-Jβ DNA sequence and sequence motifs shared among MBP83-99 specific T cell clones derived from different patients with MS

A panel of 20 CD4+ independent T cell clones was generated from seven patients with MS. All T cell clones recognized the 83-99 peptide of myelin basic protein (MBP83-99) in the context of HLA-DR2 as determined by using mouse fibroblast cells (L cells) transfected with DRB1*1501 as antigen-presenting cells. The T cell clones were characterized for TCR V gene rearrangements in reverse-transcript PCR (RT-PCR) using Vα- and Vβ-specific oligonucleotide primers and subsequently sequenced for the Vα-Jα and Vβ-Dβ-Jβ junctional regions. The sequences of the junctional regions are shown in Tables 1 and 2.

Table 1. summarizes the results of analysis with a panel of 20 independent MBP83-99 specific T cell clones characterized according to their Vα gene usage by

reverse-transcript PCR using a panel of oligonucleotide primers specific for Vα gene families (the sequence of the unique primers used are indicated by being underlined in the DNA sequence corresponding to each clone). The amino acid sequences of the "Vα", "n", "Jα", and "Cα" portions of each clone are indicated in Table 1. as follows: the "n" portions are underlined, the "Vα" and "Jα" sequences are shown in bold on their respective sides of the "n" sequence, and the "Cα" sequence is shown in normal font without being underlined. The amplified PCR products were hybridized with digoxingenin-labeled Cα cDNA probes and were analyzed subsequently for DNA sequence.

Table 2. summarizes the results of an analysis of a panel of 20 independent MBP83-99 specific T cell clones. The clones were analyzed for Vβ gene usage by reverse-transcript PCR using a set of oligonucleotide primers specific for twenty-six Vβ gene families (sequence of the specific primer for each clone is indicated by being underlined in the corresponding DNA sequence). The "Vβ", "D", "Jβ", and "Cβ" portions of each clone are indicated in Table 2. as follows: the "D" portions are underlined, the "Vβ" and "Jβ" sequences are shown in boldface type on their respective sides of the "D" sequence, and the remaining sequence, "Cβ", is in normal font (not underlined or emboldened). The amplified PCR products were hybridized with digoxingenin-labeled Cβ cDNA probes and were analyzed subsequently for DNA sequence.

Table 1: TCR Vα gene sequence specific for MBP83-99 peptide

T CELL CLONE (GenBank Accession #)	**Vgene**	**DNA or Amino Acid Sequence**	**Vα-n-Jα-Cα**
MS7-E3.1 (AF117142)	Vα22	Amino Acid	**YFCAL**SRGGSN**YKLTFGKGTLLTVNP**NIQN (SEQ ID NO: 4)
		DNA	TACTTCTGTGCTCTGAGTAGGGGAGGTAGCAACTATAAACTGACATTTGGAAAAGGAACTCTCTTAACCGTGAATCCAAATATCCAGAAC (SEQ ID NO: 5)
MS7-D2.2 (AF117143)	Vα9	Amino Acid	**YYCAL**KRNFGN**EKLTFGTGTRLTIIP**NIQN (SEQ ID NO: 6)

T CELL CLONE (GenBank Accession #)	Vgene	DNA or Amino Acid Sequence	Vα-n-Jα-Cα
		DNA	TATTACTGTGCTCTAAAAGAAACTTTGGAAATGAGAAATTAACCTTTGGGACTGGAACAAGACTCACCATCATACCCAATATCCAGAAC (SEQ ID NO: 7)
MS7-E2.6 (AF117144)	Vα17	Amino Acid	**YFCAA**SPGGSN**YKLTFGKGTLLTVNP**NIQN (SEQ ID NO: 8)
		DNA	TACTTCTGTGCAGCAAGCCCCGGAGGTAGCAACTATAAACTGACATTTGGAAAAGGAACTCTCTTAACCGTGAATCCAAATATCCAGAAC (SEQ ID NO: 9)
MS7-C3.1 (AF117145)	Vα17	Amino Acid	**YFCAA**MGDFGN**EKLTFGTGTRLTIIP**NIQN (SEQ ID NO: 10)
		DNA	TACTTCTGTGCAGCAATGGGGGACTTTGGAAATGAGAAATTAACCTTTGGGACTGGAACAAGACTCACCATCATACCCAATATCCAGAAC (SEQ ID NO: 11)
MS27-D7.16 (AF117145)	Vα17	Amino Acid	**YFCAA**MGDFGN**EKLTFGTGTRLTIIP**NIQN (SEQ ID NO: 12)
		DNA	TACTTCTGTGCAGCAATGGGGGACTTTGGAAATGAGAAATTAACCTTTGGGACTGGAACAAGACTCACCATCATACCCAATATCCAGAAC (SEQ ID NO: 13)
MS27-F3.4 (AF117145)	Vα17	Amino Acid	**YFCAA**MGDFGN**EKLTFGTGTRLTIIP**NIQN (SEQ ID NO: 14)
		DNA	TACTTCTGTGCAGCAATGGGGGACTTTGGAAATGAGAAATTAACCTTTGGGACTGGAACAAGACTCACCATCATACCCAATATCCAGAAC (SEQ ID NO: 15)
MS27-D4.4 (AF117146)	Vα22	Amino Acid	**YFCAL**SVAGGTS**YGKLTFGQGTILTVHP**NIQN (SEQ ID NO: 16)
		DNA	TACTTCTGTGCTCTGAGCGTTGCTGGTGGTACTAGCTATGGAAAGCTGACATTTGGACAAGGGACCATCTTGACTGTCCATCCAAATATCCAGAAC (SEQ ID NO: 17)
MS32-F5.12 (AF117147)	Vα16	Amino Acid	**YYCLV**GDAVRPGG**GNKLTFGTGTQLKVEL**NIQN (SEQ ID NO: 18)
		DNA	TACTACTGCCTCGTGGGTGACGCCGTGAGGCCGGGAGGAGGAAACAAACTCACCTTTGGGACAGGCACTCAGCTAAAAGTGGAACTCAATATCCAGAAC (SEQ ID NO: 19)
MS32-B9.8 (AF117147)	Vα16	Amino Acid	**YYCLV**GDAVRPGG**GNKLTFGTGTQLKVEL**NIQN (SEQ ID NO: 20)
		DNA	TACTACTGCCTCGTGGGTGACGCCGTGAGGCCGGGAGGAGGAAACAAACTCACCTTTGGGACAGGCACTCAGCTAAAAGTGGAACTCAATATCCAGAAC (SEQ ID NO: 21)

T CELL CLONE **(GenBank Accession #)**	**Vgene**	**DNA or Amino Acid Sequence**	**Vα-n-Jα-Cα**
MS37-D9.3 (AF117148)	Vα3	Amino Acid	**YFCAT**DAGGT**YKYIFGTGTRLKVLA**NIQN (SEQ ID NO: 22)
		DNA	TACTTCTGTGCTACGGACGCAGGAGGAACCTACAAATACATCTTTGGAACAGGCACCAGGCTGAAGGTTTTAGCAAATATCCAGAAC (SEQ ID NO: 23)
MS37-B9.1 (AF117149)	Vα16	Amino Acid	**YYCLV**GDI**DDMRFGAGTRLTVKP**NIQN (SEQ ID NO: 24)
		DNA	TACTACTGCCTCGTGGGTGACATCGATGACATGCGCTTTGGAGCAGGGACCAGACTGACAGTAAAACCAAATATCCAGAAC (SEQ ID NO: 25)
MS9-C.26 (AF117150)	Vα3	Amino Acid	**YFCAT**SVNTD**KLIFGTGTRLQVFP**NIQN (SEQ ID NO: 26)
		DNA	TACTTCTGTGCTACATCGGTTAACACCGACAAGCTCATCTTTGGGACTGGGACCAGATTACAAGTCTTTCCAAATATCCAGAAC (SEQ ID NO: 27)

Table 2: TCR Vβ gene sequence specific for MBP83-99 peptide

T CELL CLONE (Genbank Accession #)	Vgene	DNA or Amino Acid Sequence	Vβ-D-Jβ-Cβ
MS7-E3.1 (AF117130)	Vβ9	Amino Acid	**YFCASS**QDRFWGGTVN**TEAFFGQGTRLTVV**EDLNK (SEQ ID NO: 28)
		DNA	TATTTCTGTGCCAGCAGCCAAGATCGTTTTTGGGGGGG GACGGTGAACACTGAAGCTTTCTTTGGACAAGGCACC AGACTCACAGTTGTAGAGGACCTGAACAAG (SEQ ID NO: 29)
MS7-D2.2 (AF117131)	Vβ1	Amino Acid	**YFCASS**AM**GETQYFGPGTRLLVL**EDLKN (SEQ ID NO: 30)
		DNA	TATTTCTGTGCCAGCAGCGCTATGGGAGAGACCCAGT ACTTCGGGCCAGGCACGCGGCTCCTGGTGCTCGAGGA CCTGAAAAAC (SEQ ID NO: 31)
MS7-E2.6 (AF117132)	Vβ13.1	Amino Acid	**YFCASS**LGRAGLTY**EQYFGPGTRLTVT**EDLKN (SEQ ID NO: 32)
		DNA	TACTTCTGTGCCAGCAGCCTAGGGCGGGCGGGACTCA CCTACGAGCAGTACTTCGGGCCGGGCACCAGGCTCAC GGTCACAGAGGACCTGAAAAAC (SEQ ID NO: 33)
MS27-C3.1 (AF117132)	Vβ13.1	Amino Acid	**YFCASS**LGRAGLTY**EQYFGPGTRLTVT**EDLKN (SEQ ID NO: 34)
		DNA	TACTTCTGTGCCAGCAGCCTAGGGCGGGCGGGACTCA CCTACGAGCAGTACTTCGGGCCGGGCACCAGGCTCAC GGTCACAGAGGACCTGAAAAAC (SEQ ID NO: 35)
MS27-D7.16 (AF117132)	Vβ13.1Y	Amino Acid	**YCASS**LGRAGLTY**EQYFGPGTRLTVT**EDLKN (SEQ ID NO: 36)
		DNA	TACTTCTGTGCCAGCAGCCTAGGGCGGGCGGGACTCA CCTACGAGCAGTACTTCGGGCCGGGCACCAGGCTCAC GGTCACAGAGGACCTGAAAAAC (SEQ ID NO: 37)
MS27-F3.4 (AF117132)	Vβ13.1	Amino Acid	**YFCASS**LGRAGLTY**EQYFGPGTRLTVT**EDLKN (SEQ ID NO: 38)
		DNA	TACTTCTGTGCCAGCAGCCTAGGGCGGGCGGGACTCA CCTACGAGCAGTACTTCGGGCCGGGCACCAGGCTCAC GGTCACAGAGGACCTGAAAAAC (SEQ ID NO: 39)
MS27-D4.4 (AF117133)	Vβ9	Amino Acid	**YFCASS**PTVNY**GYTFGSGTRLTVV**EDLNK (SEQ ID NO: 40)

T CELL CLONE (Genbank Accession #)	Vgene	DNA or Amino Acid Sequence	Vβ-D-Jβ-Cβ
		DNA	TATTTCTGTGCCAGCAGCCCGACAGTTAACTATGGCTA CACCTTCGGTTCGGGGACCAGGTTAACCGTTGTAGAG GACCTGAACAAG (SEQ ID NO: 41)
MS32-F5.12 (AF117134)	Vβ13.1	Amino Acid	**YFCASS**YSIRGQGN**EQYFGPGTRLTVT**EDLKN (SEQ ID NO: 42)
		DNA	TACTTCTGTGCCAGCAGTTACTCGATTAGGGGACAGG GTAACGAGCAGTACTTCGGGCCGGGCACCAGGCTCAC GGTCACAGAGGACCTGAAAAAC (SEQ ID NO: 43)
MS32-B9.8 (AF117134)	Vβ13.1	Amino Acid	**YFCASS**YSIRGQGN**EQYFRPGTRLTVT**EDLKN (SEQ ID NO: 44)
		DNA	TACTTCTGTGCCAGCAGTTACTCGATTAGGGGACAGG GTAACGAGCAGTACTTCCGGCCGGGCACCAGGCTCAC GGTCACAGAGGACCTGAAAAAC (SEQ ID NO: 45)
MS37-D9.3 (AF119246)	Vβ7	Amino Acid	**YLCASS**QDRVA**PQYFGPGTRLLVL**EDLKN (SEQ ID NO: 46)
		DNA	TATCTCTGTGCCAGCAGCCAAGATCGGGTTGCGCCAC AGTACTTCGGGCCAGGCACGCGGCTCCTGGTGCTCGA GGACCTGAAAAAC (SEQ ID NO: 47)
MS37-B9.1 (AF117135)	Vβ17	Amino Acid	**YLCASS**TRQGPQE**TQYFGPGTRLLVL**EDLKN (SEQ ID NO: 48)
		DNA	TATCTCTGTGCCAGTAGTACCCGGCAAGGACCTCAAG AGACCCAGTACTTCGGGCCAGGCACGCGGCTCCTGGT GCTCGAGGACCTGAAAAAC (SEQ ID NO: 49)
MS8-D2.7 (AF117136)	Vβ8	Amino Acid	**YLCASS**LGQGAY**EQYFGPGTRLTVT**EDLKN (SEQ ID NO: 50)
		DNA	TATCTCTGTGCCAGCAGCTTAGGACAGGGGGCTTACG AGCAGTACTTCGGGCCGGGCACCAGGCTCACGGTCAC AGAGGACCTGAAAAAC (SEQ ID NO: 51)
MS8-A2.7 (AF117136)	Vβ8	Amino Acid	**YLCASS**LGQGAY**EQYFGPGTRLTVT**EDLKN (SEQ ID NO: 52)
		DNA	TATCTCTGTGCCAGCAGCTTAGGACAGGGGGCTTACG AGCAGTACTTCGGGCCGGGCACCAGGCTCACGGTCAC AGAGGACCTGAAAAAC (SEQ ID NO: 53)
MS8-A1.15 (AF117136)	Vβ8	Amino Acid	**YLCASS**LGQGAY**EQYFGPGTRLTVT**EDLKN (SEQ ID NO: 54)

T CELL CLONE (Genbank Accession #)	**Vgene**	**DNA or Amino Acid Sequence**	**Vβ-D-Jβ-Cβ**
		DNA	TATCTCTGTGCCAGCAGCTTAGGACAGGGGGCTTACGAGCAGTACTTCGGGCCGGGCACCAGGCTCACGGTCACAGAGGACCTGAAAAAC (SEQ ID NO: 55)
MS8-D1.3 (AF117137)	Vβ8	Amino Acid	**YFCASS**LQVYSPLH**FGNGTRLTVT**EDLNK (SEQ ID NO: 56)
		DNA	TACTTCTGTGCCAGCAGTTTACAAGTGTATTCACCCCTCCACTTTGGGAACGGGACCAGGCTCACTGTGACAGAGGACCTGAACAAG (SEQ ID NO: 57)
MS33-D1.2 (AF117138)	Vβ12	Amino Acid	**YFCAIS**ESIGTG**TEAFFGQGTRLTVV**EDLNK (SEQ ID NO: 58)
		DNA	TACTTCTGTGCCATCAGTGAGTCGATTGGTACGGGAACTGAAGCTTTCTTTGGACAAGGCACCAGACTCACAGTTGTAGAGGACCTGAACAAG (SEQ ID NO: 59)
MS33-D3.3 (AF117138)	Vβ12	Amino Acid	**YFCAIS**ESIGTG**TEAFFGQGTRLTVV**EDLNK (SEQ ID NO: 60)
		DNA	TACTTCTGTGCCATCAGTGAGTCGATTGGTACGGGAACTGAAGCTTTCTTTGGACAAGGCACCAGACTCACAGTTGTAGAGGACCTGAACAAG (SEQ ID NO: 61)
MS33-D8.1 (AF117139)	Vβ3	Amino Acid	**YLCAS**RDRSY**EQYFGPGTRLTVT**EDLKN (SEQ ID NO: 62)
		DNA	TACCTCTGTGCCAGCCGGGACAGGTCCTACGAGCAGTACTTCGGGCCGGGCACCAGGCTCACGGTCACAGAGGACCTGAAAAAC (SEQ ID NO: 63)
MS9-C.26 (AF117140)	Vβ12	Amino Acid	**YFCAIS**EGSSSGN**TIYFGEGSWLTVV**EDLNK (SEQ ID NO: 64)
		DNA	TACTTCTGTGCCATCAGTGAGGGGTCCAGCTCTGGAAACACCATATATTTTGGAGAGGGAAGTTGGCTCACTGTTGTAGAGGACCTGAACAAG (SEQ ID NO: 65)
MS35-C7.2 (AF117141)	Vβ2	Amino Acid	**FYICS**AID**GYTFGSGTRLTVV**EDLNK (SEQ ID NO: 66)
		DNA	TTCTACATCTGCAGTGCTATAGACGGCTACACCTTCGGTTCGGGGACCAGGTTAACCGTTGTAGAGGACCTGAACAAG (SEQ ID NO: 67)

Although the Vα and Vβ rearrangements varied between individual MBP83-99 T cell clones, many of these independent T cell clones derived from a given individual shared identical Vα and Vβ chains with the same Vα-Jα and Vβ-Dβ-Jβ junctional region sequences. The finding is consistent with *in vivo* clonal expansion of MBP83-99 specific T cells in given patients with MS as reported previously (Vandevyver 1995, Wucherpfenning 1994).

Interestingly, as indicated in Tables 1 and 2, an independent T cell clone (clone E2.6) derived from one patient (MS-1) shared the same Vβ13.1 and Vα17 with 3 of 4 T cell clones (clones C3.1, D7.16 and F3.4) obtained from another patient (MS-2). Vβ13.1 of these T cell clones shared an identical DNA sequence within the Vβ-Dβ-Jβ junctional region.

Example 2

Vβ-Dβ-Jβ-specific oligonucleotide primers were highly specific and sensitive in detecting corresponding DNA sequences present in original MBP83-99 T cell clones as well as in PBMC containing original MBP83-99 T cells

A set of 14 oligonucleotide primers were synthesized according to DNA sequences within the Vβ-Dβ-Jβ junctional regions of independent MBP83-99 T cell clones and subsequently examined for their specificity in RT-PCR. The DNA sequences of these oligonucleotide primers are shown in Table 3.

Table 3 DNA sequences of Vβ-Dβ-Jβ -specific oligonucleotide primers

T cell clone	DNA sequence	SEQ ID NO
MS1-E3.1	AGCAGCCAAGATCGTTTTTGG	SEQ ID NO: 68
MS1-E2.6	CTAGGGCGGGCGGGACTCACCTAC	SEQ ID NO: 69
MS2-C3.1	CTAGGGCGGGCGGGACTCACCTAC	SEQ ID NO: 70
MS2-D4.4		
MS3-F5.12	TACTCGATTAGGGGACAGGGTAAC	SEQ ID NO: 71
MS3-B9.8		
MS4-D9.3	CAAGATCGGGTTGCGCCA	SEQ ID NO: 72
MS4-B9.1	ACCCGGCAAGGACCTCAAGAGACC	SEQ ID NO: 73
MS5-D2.7	AGCTTAGGACAGGGGGCT	SEQ ID NO: 74
MS5-D1.3		
MS6-D8.1	GCCAGCCGGGACAGGTCC	SEQ ID NO: 75

MS6-D1.2	GAGTAGATTGGTACGGGA	SEQ ID NO: 76
MS7-C.26		
MS8-C7.2	TACATCTGAAGTGCTATAGAC	SEQ ID NO: 77

These Vβ-Dβ-Jβ-specific primers bound exclusively to DNA sequences present in the original MBP83-99 T cell clones and did not bind to the sequences derived from unrelated MBP83-99 T cell clones (Figure 2), suggesting their high specificity for the original Vβ-Dβ-Jβ DNA sequences. The only exception was noted for clone MS1-E2.6 and clone MS2-C3.1, in which the same primer bound to a Vβ-Dβ-Jβ junctional DNA sequence shared by both T cell clones.

Given the specificity of the Vβ-Dβ-Jβ oligonucleotide primers and high sensitivity of PCR detection system, we asked whether this two-step PCR detection system using 5' Vβ primers and Vβ-Dβ-Jβ-specific oligonucleotide primers could be used to detect corresponding Vβ-Dβ-Jβ DNA sequences present in peripheral blood mononuclear cells (PBMC) specimens from which the MBP83-99 T cell clones originated. The results of two separate experiments showed positive detection of the Vβ-Dβ-Jβ sequences in original PBMC specimens. Thus, the findings demonstrated that the PCR detection system where Vβ-Dβ-Jβ sequence served as a fingerprint was specific and sensitive in tracing MBP83-99 T cells present in peripheral blood mononuclear cells by probing identical DNA sequences.

Example 3

The detection of a common Vβ-Dβ-Jβ DNA sequence in PBMC specimens derived from different patients with MS and healthy individuals

Next, we examined whether DNA sequences corresponding to Vβ-Dβ-Jβ junctional regions of the MBP83-99 T cell clones could be detected in PBMC specimens randomly selected from a group of patients with MS and healthy individuals. The same PCR amplification system using primers specific for corresponding Vβ families (in the first PCR) and primers specific for Vβ-Dβ-Jβ sequences (in the second semi-nested PCR) was employed. It was combined with Southern blot analysis with corresponding Vβ-Dβ-Jβ probes to perform hybridization. Given the specific requirements of the two-step PCR detection system and specificity of the Vβ-Dβ-Jβ primers and probes, the identified DNA

sequences would derive from specific TCR Vβ chains and represent either identical or similar to Vβ-Dβ-Jβ sequences of interest.

The results indicated that only one Vβ-Dβ-Jβ oligonucleotide primer (MS1-E2.6, Vβ13.1-LGRAGLTY) detected complementary TCR Vβ13.1 DNA sequence in 15 of 48 (31%) PBMC specimens obtained from different patients with MS. Thus, the finding indicates the presence of MBP83-99 T cells expressing Vβ13.1-LGRAGLTY in these patients with MS. Under similar experimental conditions, the same primer also detected corresponding DNA sequence in 5 of 20 (25%) PBMC specimens derived from healthy individuals. The remaining 13 Vβ-Dβ-Jβ primers failed to identify any sequence signals in the same panel of PBMC specimens. The results were reproducible in three separate experiments. The identified DNA products amplified by the E2.6 primer originated from T cells expressing Vβ13.1 because a Vβ13.1-specific primer was used in the first PCR for amplification.

Furthermore, the identified Vβ13.1-LGRAGLTY sequence was also amplified in 13 of 24 (54%) short-term MBP83-99 T cell lines generated from five patients with MS (MS-35, MS36 and MS39) whose PBMC specimens were shown to contain the Vβ13.1-LGRAGLTY sequence. The results thus confirmed that the Vβ13.1-LGRAGLTY DNA sequence detected in the PBMC specimens originated from T cells recognizing MBP83-99. The finding also suggests that MBP83-99 T cells expressing the Vβ13.1-LGRAGLTY sequence represent all or the majority of MBP83-99 T cell lines found in some patients with MS.

A combined PCR-DNA hybridization detection system where Vβ-Dβ-Jβ sequences were used as a fingerprint provided a powerful tool in tracing antigen-specific T cells by detecting identical Vβ-Dβ-Jβ junctional sequences. The high specificity and sensitivity of the detection system allowed the identification of specific Vβ-Dβ-Jβ sequences in peripheral blood T cells. The present study demonstrated for the first time that a common subset of Vβ13.1 T cells that recognize the immunodominant 83-99 peptide of MBP and uniformly express an identical Vβ-Dβ-Jβ sequence is present in approximately 30% of patients with MS. The conclusion is made based on step-wise experiments described herein. First, the identical DNA sequence (Vβ13.1-LGRAGLTY)

was found among independent MBP83-99 T cell clones derived from different patients with MS. Second, the sequence was identified in cDNA products amplified from TCR Vβ13.1 of PBMC specimens obtained from different patients with MS. Third, the DNA sequence was detected in short-term independent MBP83-99 T cell lines generated from PBMC specimens that were shown to contain the Vβ13.1-LGRAGLTY sequence. MBP83-99 T cells expressing the Vβ13.1-LGRAGLTY sequence seem to represent all or the majority of the MBP83-99 T cell lines generated from some patients with MS. Finally, the presence of Vβ13.1-LGRAGLTY sequence in PBMC specimens was confirmed by recombinant DNA cloning and direct DNA sequencing.

Furthermore, it is not surprising that MBP83-99 T cells expressing the common Vβ13.1-LGRAGLTY sequence are also present in some healthy individuals. Studies reported so far indicate that MBP-reactive T cells, including T cells recognizing the immunodominant 83-99 peptide, are also present in some healthy individuals (Zhang 1994, Ota 1990). However, there is a functional difference that these T cells undergo *in vivo* activation and clonal expansion in patients with MS, as opposed to healthy individuals (Zhang 1994).

These Vβ13.1 MBP83-99 T cells sharing the common Vβ-Dβ-Jβ sequence may represent a significant fraction of MBP83-99 T cells found in some patients with MS. This possibility is supported by the observation that the Vβ13.1-LGRAGLTY sequence was present in 40% of short-term MBP83-99 T cell lines generated from patients with MS after two stimulation cycles.

The identified common Vβ-Dβ-Jβ sequence may be used as a specific marker in a quantitative PCR detection system to detect a common subset of MBP83-99 T cells in the blood and cerebrospinal fluid in a large group of MS patients for the purpose of monitoring *in vivo* clonal expansion and *in vivo* activity potentially associated with the disease. This method will be superior to conventional cell culture-based assays because *in vitro* selection and expansion of MBP-reactive T cells are often hampered by various inhibitory factors inherent in cell culture. This is consistent with a recent study where the frequency of MBP-reactive T cells was found to be surprisingly high in patients with MS

when direct ex vivo analysis was employed to quantify MBP-reactive T cells (Hafler as last author JEM 1997).

Furthermore, synthetic peptides corresponding to the TCR have been shown to induce anti-idiotypic T cell responses to MBP-reactive T cells in patients with MS (Chou et al, J.I.). Therefore, a TCR peptide containing a common CDR3 sequence may be of great potential in eliciting anti-idiotypic T cells to suppress a specific subset of MBP-reactive T cells in a group of patients whose MBP83-99 T cells bear the common CDR3 sequence motif. Immunization with such a common CDR3 peptide would be advantageous over CDR2 peptides or individual-dependent CDR3 peptides as a potential treatment procedure in patients with MS (Vandenbark 1996).

All of the compositions and/or methods disclosed and claimed herein can be made and executed without undue experimentation in light of the present disclosure. While the compositions and methods of this invention have been described in terms of preferred embodiments, it will be apparent to those of skill in the art that variations may be applied to the compositions and/or methods and in the steps or in the sequence of steps of the method described herein without departing from the concept, spirit and scope of the invention. More specifically, it will be apparent that certain agents which are both chemically and physiologically related may be substituted for the agents described herein while the same or similar results would be achieved. All such similar substitutes and modifications apparent to those skilled in the art are deemed to be within the spirit, scope and concept of the invention as defined by the appended claims.

SEQUENCE LISTING

<110> Jingwu, Zhang Z.

<120> T Cell Receptor VB-DB-JB Sequence and Methods For Its Detection

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CLAIMS:

1. An oligonucleotide of about 15 to 30 nucleotides in length, comprising at least 10 contiguous nucleotides of SEQ ID NO:1, or the nucleic acid complementary thereto.

2. The oligonucleotide of claim 1, which comprises at least 15 contiguous nucleotides of SEQ ID NO:1, or the nucleic acid complementary thereto.

3. The oligonucleotide of claim 1, which comprises the sequence of SEQ ID NO:1, or the nucleic acid complementary thereto.

4. A primer pair, comprising:

(a) a first primer of about 15 to 30 nucleotides in length, comprising at least 10 contiguous nucleotides of SEQ ID NO:1, or the nucleic acid complementary thereto; and

(b) a second primer comprising a nucleic acid of about 15 and 30 nucleotides in length that does not comprise the sequence of (a) and is found in the region from Vβ to Jβ of the Vβ13.1 gene in T cell receptor T cells,

wherein the sequences of said first and second primers are not found on the same strand of the T cell receptor gene.

5. The primer pair of claim 4, wherein the Vβ13.1 gene sequence is SEQ ID NO:2.

6. An oligonucleotide probe comprising:

(a) an oligonucleotide of about 10 to 30 nucleotides in length, comprising at least 10 contiguous nucleotides of SEQ ID NO:1, or the nucleic acid complementary thereto; and

(b) a labeling moiety.

7. The oligonucleotide probe of claim 6, wherein the labeling moiety is selected from ^{32}P or digoxingenin.

8. A method of detecting MBP83-99 Vβ13.1 T cells expressing a T cell receptor LGRAGLTY motif, comprising:

(a) obtaining a nucleic acid sample from MBP83-99 Vβ13.1 T cells;

(b) contacting the nucleic acid sample with a primer pair selected or derived from:

(i) a first oligonucleotide of about 15 to 30 nucleotides in length, comprising at least 10 contiguous nucleotides of SEQ ID NO:1, or the nucleic acid complementary thereto; and

(ii) a second oligonucleotide of about 15 and 30 nucleotides in length that does not comprise the sequence of the first oligonucleotide and is found in the region from Vβ to Jβ of the Vβ13.1 gene in T cell receptor T cells,

wherein the sequences of the first and second oligonucleotides are not found on the same strand of the T cell receptor gene; and

(c) detecting the presence of the nucleic acid encoding the LGRAGLTY motif.

9. The method of claim 8, wherein the Vβ13.1 gene sequence is SEQ ID NO:2.

10. The method according to claim 8, wherein a fragment of the nucleic acid sample is amplified by polymerase chain reaction (PCR).

11. The method according to claim 10, wherein the detection step comprises probing with an oligonucleotide probe comprising:

(a) an oligonucleotide, which comprises the sequence of SEQ ID NO:1, or the nucleic acid complementary thereto; and,

(b) a labeling moiety.

12. The method according to claim 10, wherein the detection step comprises autoradiography.

13. A test kit comprising a first oligonucleotide of about 15-30 nucleotides in length: said first oligonucleotide comprising at least 10 contiguous nucleotides of SEQ ID NO:1, or the nucleic acid complementary thereto.

14. The test kit of claim 13, further comprising: a second oligonucleotide of about 15 and 30 nucleotides in length that does not comprise the sequence of said first oligonucleotide and is found in the region from Vβ to Jβ of the Vβ13.1 gene in T cell receptor T cells, wherein the sequences of the first and second oligonucleotides are not found on the same strand of the T cell receptor gene.

15. The test kit of claim 14, wherein the Vβ13.1 gene sequence is SEQ ID NO:2.

16. The test kit of claim 13, further comprising a labeling moiety, wherein the labeling moiety is selected from ^{32}P or digoxingenin.

17. A method of treating an autoimmune disease, in a human comprising:

(a) obtaining MBP83-99 Vβ13.1 T cells from a human;

(b) obtaining a nucleic acid sample from MBP83-99 Vβ13.1 T cells;

(c) contacting the nucleic acid sample with a primer pair selected or derived from:

(i) a first oligonucleotide of about 15 to 30 nucleotides in length, comprising at least 10 contiguous nucleotides of SEQ ID NO:1, or the nucleic acid complementary thereto; and

(iii) a second oligonucleotide of about 15 and 30 nucleotides in length that does not comprise the sequence of said first oligonucleotide and is found in the region from Vβ to Jβ of the Vβ13.1 gene in T cell receptor T cells,

wherein the sequences of said first and second oligonucleotides are not found on the same strand of the T cell receptor gene; and

(d) detecting the presence of the nucleic acid encoding the LGRAGLTY motif; and, if the nucleic acid is detected,

(e) administering an Lue Gly Arg Ala Gly Leu Thr Tyr (SEQ ID NO: 3) peptide to the human.

18. The method of 17, wherein the Vβ13.1 gene sequence is SEQ ID NO:2.

19. The method of claim 17, wherein the administering step further comprises administering a T cell activation marker peptide.

20. A method of monitoring an autoimmune disease, comprising:

(A) obtaining MBP83-99 Vβ13.1 T cells from a human;

(B) detecting the presence of a nucleic acid encoding a LGRAGLTY motif by

(i) obtaining a nucleic acid sample from MBP83-99 Vβ13.1 T cells;

(ii) contacting the nucleic acid sample with a primer pair selected or derived from:

(a) a first oligonucleotide of about 15 to 30 nucleotides in length, comprising at least 10 contiguous nucleotides of SEQ ID NO:1, or the nucleic acid complementary thereto; and

(b) a second oligonucleotide of about 15 and 30 nucleotides in length that does not comprise the sequence of said first oligonucleotide and is found in the region from Vβ to Jβ of the Vβ13.1 gene in T cell receptor T cells,

wherein the sequences of said first and second oligonucleotides are not found on the same strand of the T cell receptor gene; and

(c) detecting the presence of the nucleic acid encoding the LGRAGLTY motif; and, if the nucleic acid is detected,

(C) quantifying the amount of the nucleic acid.

21. The method of 20, wherein the Vβ13.1 gene sequence is SEQ ID NO:2.

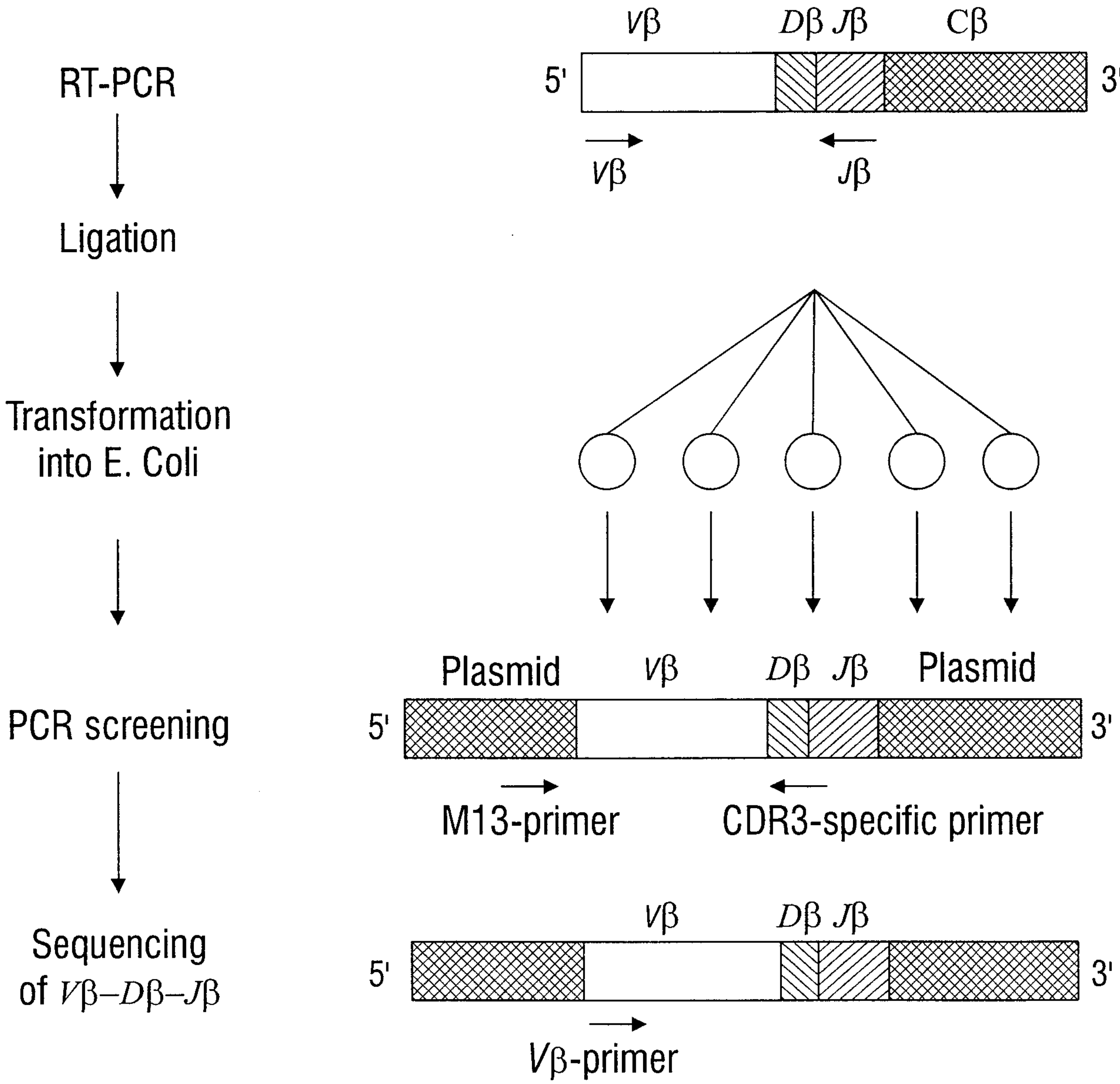
RT-PCR
Ligation
Transformation into E. Coli
PCR screening
Sequencing of Vβ–Dβ–Jβ
Vβ
Dβ Jβ
Cβ
5'
3'
Vβ
Jβ
Plasmid
Vβ
Dβ Jβ
Plasmid
5'
3'
M13-primer
CDR3-specific primer
Vβ
Dβ Jβ
5'
3'
Vβ-primer

FIG. 1

T cell reactivity (CPM±SD

Alanine substituted peptides	MS1-E2.6	MS1-C3.1	MS1-E3.1
83-ENPVVHFFKNIVTPRTP-99	74,189 ± 6,224	28,966 ± 1,100	31,236 ± 3,099
A----------------	59,328 ± 2,583	42,446 ± 676	38,880 ± 1,483
-A---------------	68,881 ± 3,155	33,165 ± 1,883	31,243 ± 1,036
--A--------------	64,901 ± 377	27,019 ± 3.085	24,487 ± 731
---A-------------	65,519 ± 588	21,340 ± 1,288	34,289 ± 357
----A------------	65,205 ± 241	35,032 ± 5,649	34,080 ± 2,274
-----A-----------	74,224 ± 526	16,199 ± 412	35,242 ± 300
------A----------	67,916 ± 1,979	34,437 ± 88	16,853 ± 690
-------A---------	2,504 ± 519	907± 10	334 ± 38
--------A--------	51,052 ± 4,329	26,400 ± 3,969	12,577 ± 610
---------A-------	1,787 ± 120	3,364 ± 275	1,658 ± 78
----------A------	69,699 ± 3,649	7,649 ± 337	16,598 ± 440
-----------A-----	1,710 ± 34	35,340 ± 476	42,982 ± 1,605
------------A----	48,169 ± 1,418	32,109 ± 570	21,977 ± 1,354
-------------A---	70,946 ± 1,326	23,662 ± 529	10,237 ± 22
--------------A--	2,389 ± 473	21,401 ± 432	2,424 ± 126
---------------A-	1,859 ± 110	32,035 ± 257	36,930 ± 623
----------------A	1,569 ± 32	31,506 ± 351	34,389 ± 457
Medium alone	1,763 ± 132	999 ± 57	715 ± 53

FIG. 2

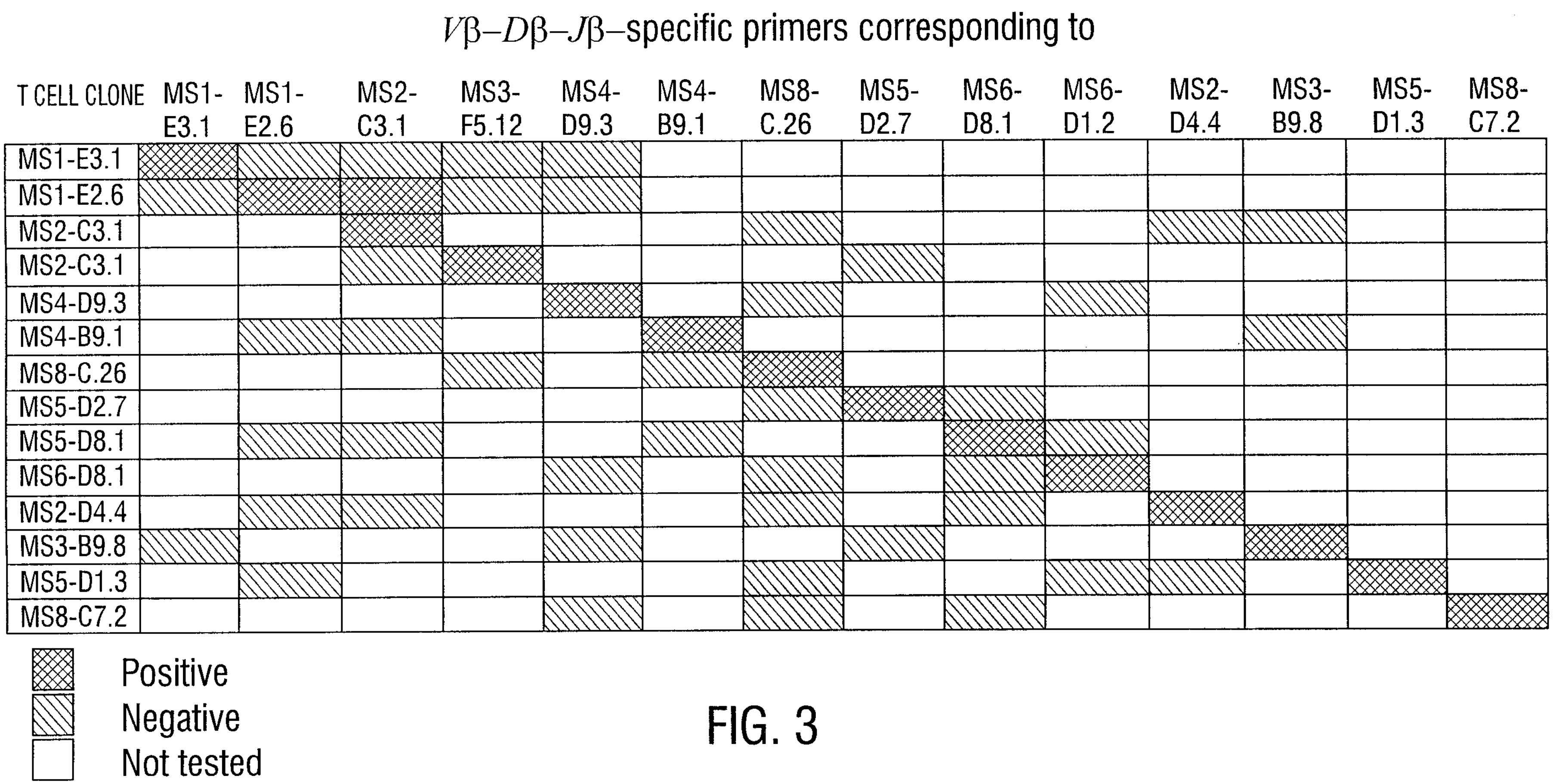
$V\beta$–$D\beta$–$J\beta$–specific primers corresponding to
T CELL CLONE
MS1-E3.1
MS1-E2.6
MS2-C3.1
MS3-F5.12
MS4-D9.3
MS4-B9.1
MS8-C.26
MS5-D2.7
MS6-D8.1
MS6-D1.2
MS2-D4.4
MS3-B9.8
MS5-D1.3
MS8-C7.2
MS1-E3.1
MS1-E2.6
MS2-C3.1
MS2-C3.1
MS4-D9.3
MS4-B9.1
MS8-C.26
MS5-D2.7
MS5-D8.1
MS6-D8.1
MS2-D4.4
MS3-B9.8
MS5-D1.3
MS8-C7.2
Positive
Negative
Not tested

FIG. 3

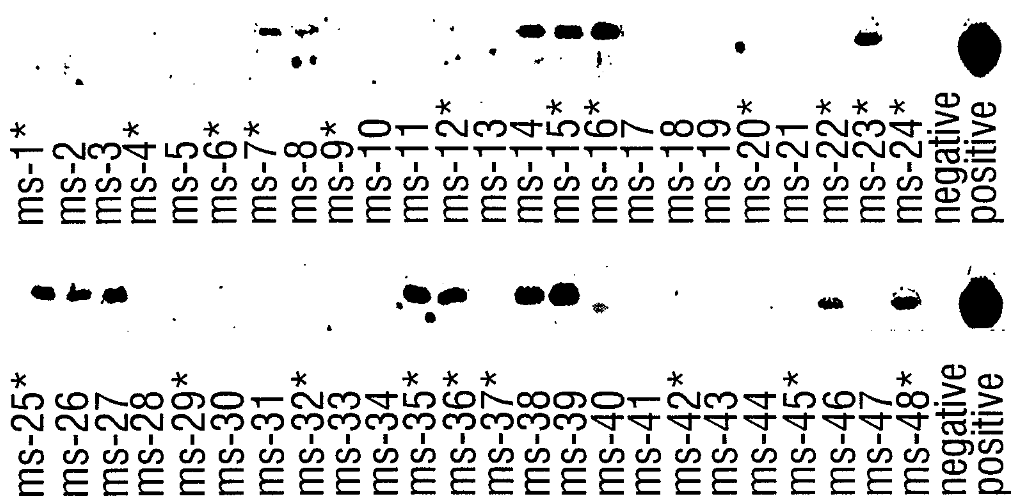
ms-1*
ms-2
ms-3
ms-4*
ms-5
ms-6*
ms-7*
ms-8
ms-9*
ms-10
ms-11
ms-12*
ms-13
ms-14
ms-15*
ms-16*
ms-17
ms-18
ms-19
ms-20*
ms-21
ms-22*
ms-23*
ms-24*
negative
positive
ms-25*
ms-26
ms-27
ms-28
ms-29*
ms-30
ms-31
ms-32*
ms-33
ms-34
ms-35*
ms-36*
ms-37*
ms-38
ms-39
ms-40
ms-41
ms-42*
ms-43
ms-44
ms-45*
ms-46
ms-47
ms-48*
negative
positive

FIG. 4

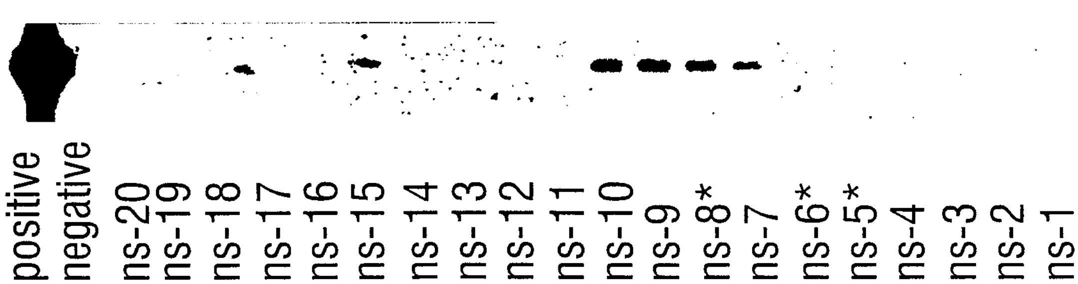
positive
negative
ns-20
ns-19
ns-18
ns-17
ns-16
ns-15
ns-14
ns-13
ns-12
ns-11
ns-10
ns-9
ns-8*
ns-7
ns-6*
ns-5*
ns-4
ns-3
ns-2
ns-1

FIG. 5

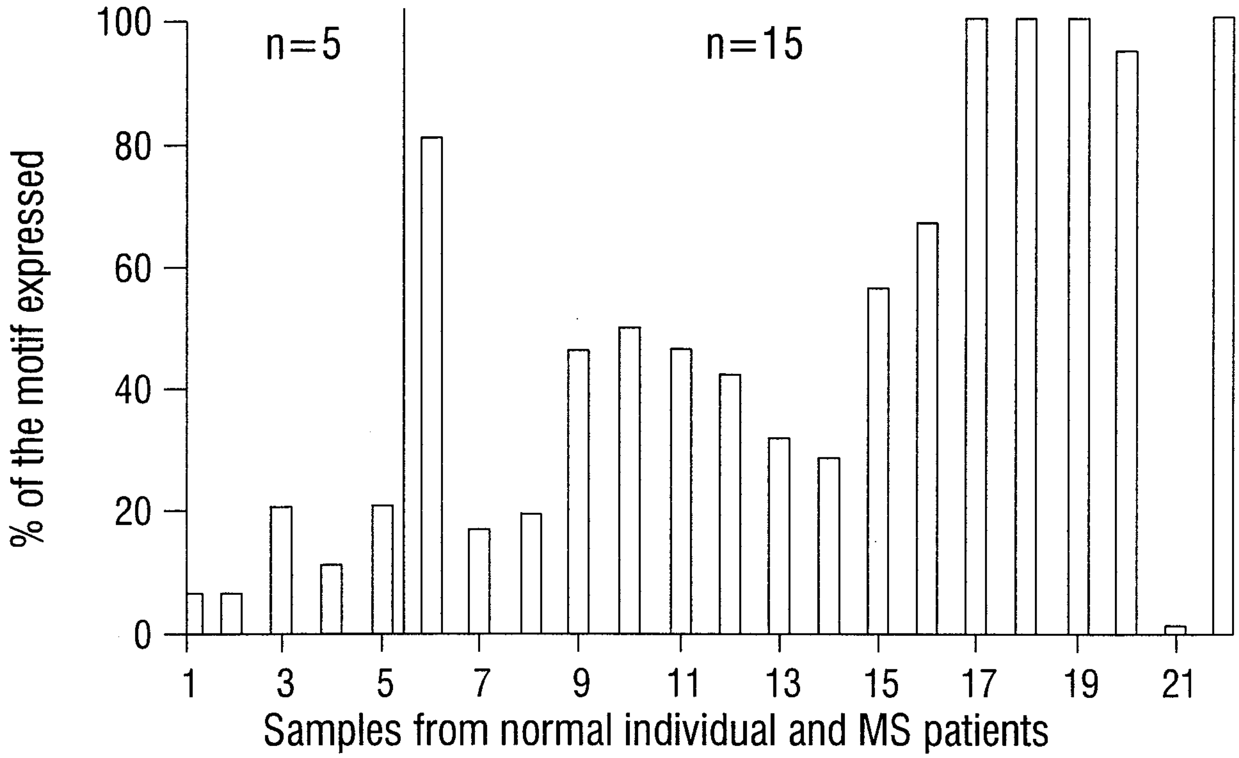
% of the motif expressed
100
80
60
40
20
0
n=5
n=15
1
3
5
7
9
11
13
15
17
19
21
Samples from normal individual and MS patients

FIG. 6

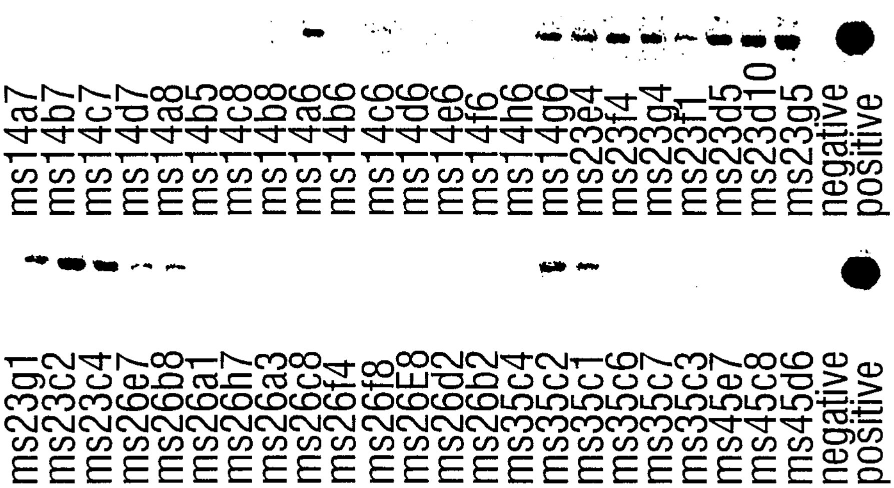
ms14a7
ms14b7
ms14c7
ms14d7
ms14a8
ms14b5
ms14c8
ms14b8
ms14a6
ms14b6
ms14c6
ms14d6
ms14e6
ms14f6
ms14h6
ms14g6
ms23e4
ms23f4
ms23g4
ms23f1
ms23d5
ms23d10
ms23g5
negative
positive
ms23g1
ms23c2
ms23c4
ms26e7
ms26b8
ms26a1
ms26h7
ms26a3
ms26c8
ms26f4
ms26f8
ms26E8
ms26d2
ms26b2
ms35c4
ms35c2
ms35c1
ms35c6
ms35c7
ms35c3
ms45e7
ms45c8
ms45d6
negative
positive

FIG. 7

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US00/40006

A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) :C12Q 1/68; C07H 21/02, 21/04; A01N 37/18; A61K 38/00
US CL :435/6; 536/23.1, 24.3; 514/2
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 435/6; 536/23.1, 24.3; 514/2

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

Please See Extra Sheet.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	BOEHRINGER MANNHEIM CORPORATION. Boehringer Mannheim Biochemicals 1993 Catalog. 1993, page 87, see entire document.	1-3, 6-7, 13 and 16
A, P	HONG et al. A Common TCR V-D-J Sequence in Vβ13.1 T Cells Recognizing an Immunodominant Peptide of Myelin Basic Protein in Multiple Sclerosis. Journal of Immunology. September 1999, Vol. 163, No. 6, pages 3530-3538, see the entire document.	1-21
A	KOZOVSKA et al. T Cell Recognition Motifs of an Immunodominant Peptide of Myelin Basic Protein in Patients with Multiple Sclerosis: Structural Requirements and Clinical Implications. European Journal of Immunology. June 1998, Vol. 28, No. 6, pages 1894-1901, see the entire document.	1-21

[X] Further documents are listed in the continuation of Box C. [ ] See patent family annex.

* Special categories of cited documents:

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"E" earlier document published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
15 MAY 2000	12 JUN 2000
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703) 305-3230	Authorized officer ETHAN WHISENANT, PH.D. Telephone No. (703) 308-0196

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	ZANG et al. Restricted TCR Vα Gene Rearrangements in T Cells Recognizing an Immunodominant Peptide of Myelin Basic Protein in DR2 Patients with Multiple Sclerosis. International Immunology. July 1998, Vol. 10, No. 7, pages 991-998, see the entire document.	1-21
A	Database CAPLUS, Accession No. 1998:787586, ZHANG, J. 'Emerging Therapeutic Targets in Multiple Sclerosis: Suppression and Elimination of Myelin-Autoreactive T-Lymphocytes,' abstract, Emerging Therapeutic Targets. 1998, Vol. 2, No. 2, pages 137-156, see entire abstract.	17-19

B. FIELDS SEARCHED

Electronic data bases consulted (Name of data base and where practicable terms used):

USPATFULL, MEDLINE, CAPLUS

search terms :T cell receptor, gene, autoimmune disease